

Latest results from the CUORE experiment

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The CUORE experiment

CUORE (Cryogenic Underground Observatory for Rare Events)
 Located deep underground (3600 m.w.e) at the Laboratori Nazionali del Gran Sasso (Assergi, Italy)

Primary goal: Search for $0\nu\beta\beta$ of ^{130}Te

- $Q_{\beta\beta}(^{130}\text{Te})$ 2527.5 keV
- ^{130}Te is the isotope with the highest isotopic abundance (34.2%) among the $\beta\beta$ candidates
- Nominal background index in the ROI: 0.01 counts/keV/kg/yr
- Goal energy resolution at $Q_{\beta\beta}$: 5 keV

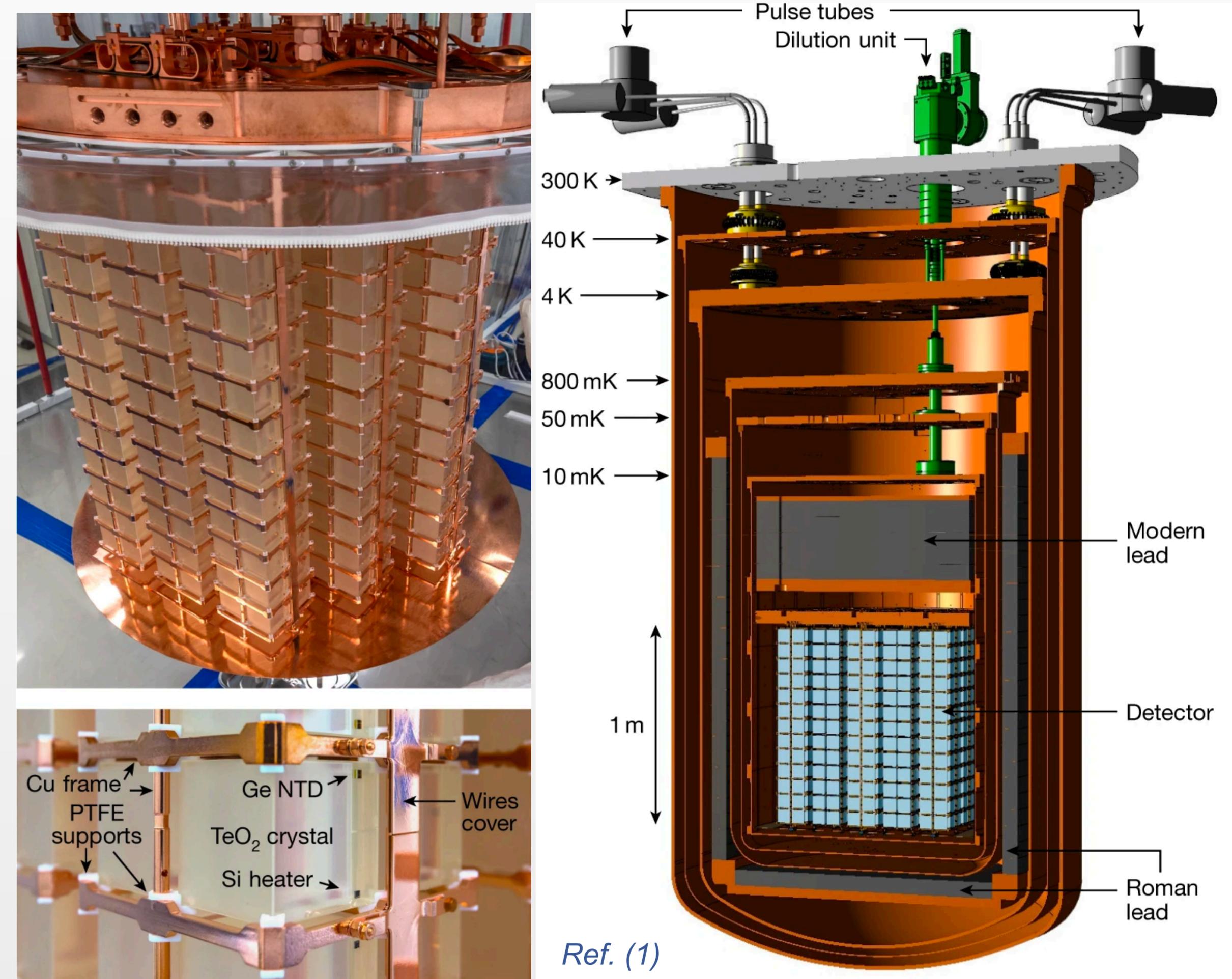
Detectors: 988 TeO_2 crystals,

- Divided in 19 towers, total mass 742 kg (206 kg of ^{130}Te)
- TeO_2 crystals: $0\nu\beta\beta$ source material, operated as cryogenic calorimeters at ~ 10 mK

Cryogenic infrastructure:

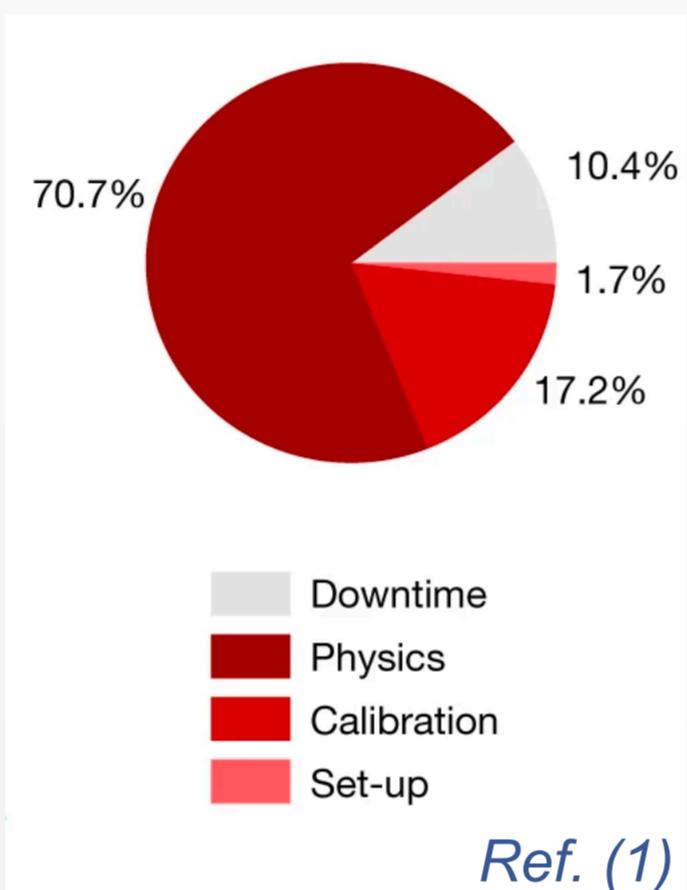
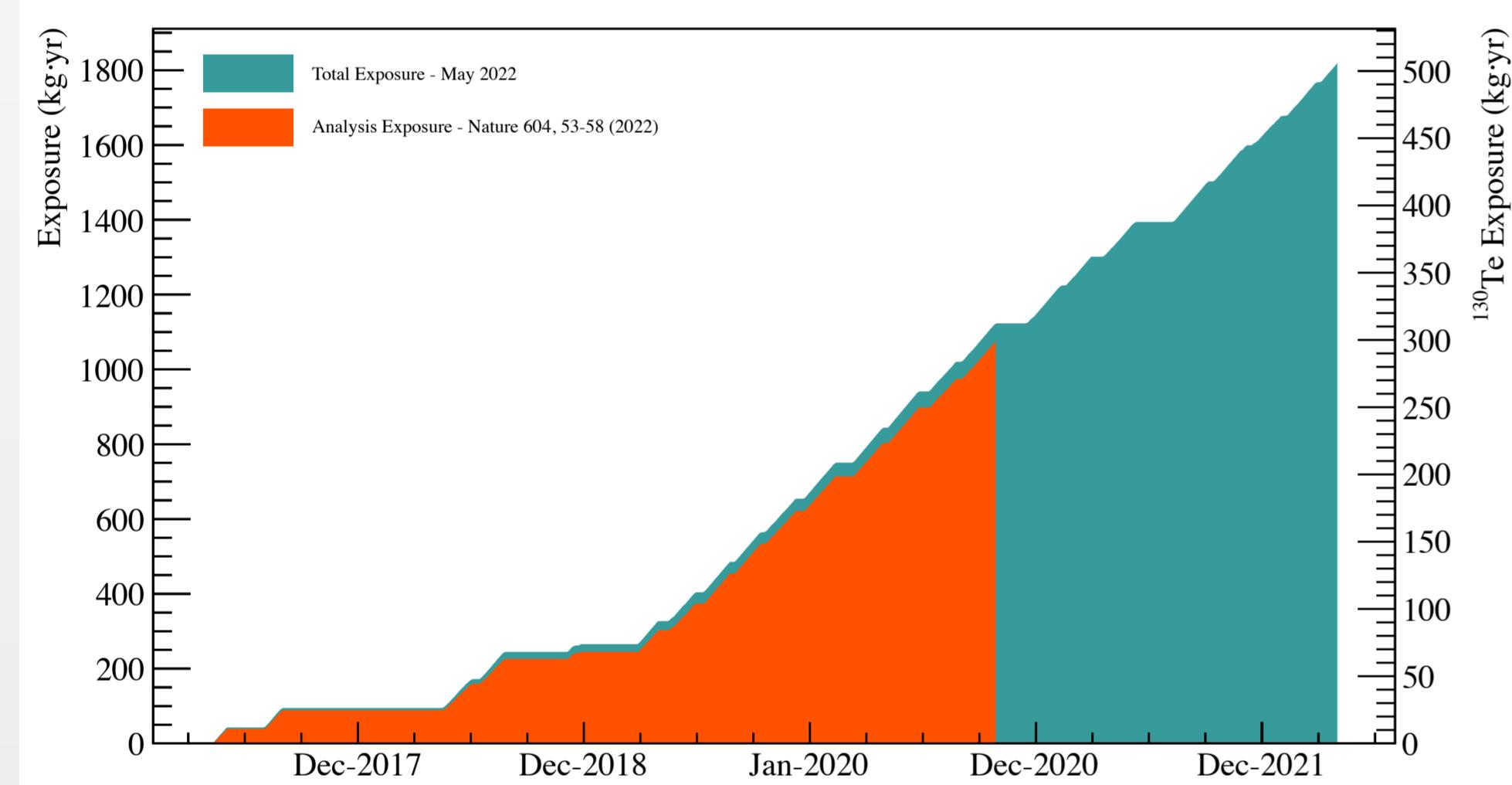
- Multistage cryogen-free cryostat: Nested vessels at decreasing temperature
- 5 Pulse Tube Cryo-coolers 40W @ 40K, 1.2W @ 4K
- Custom 3He/4He DU 2mW @ 100mK, 4 μ W @ 10mK
- Mechanical vibration isolation: Reduce energy dissipation by vibrations

Refs. (1-5)



CUORE data-taking

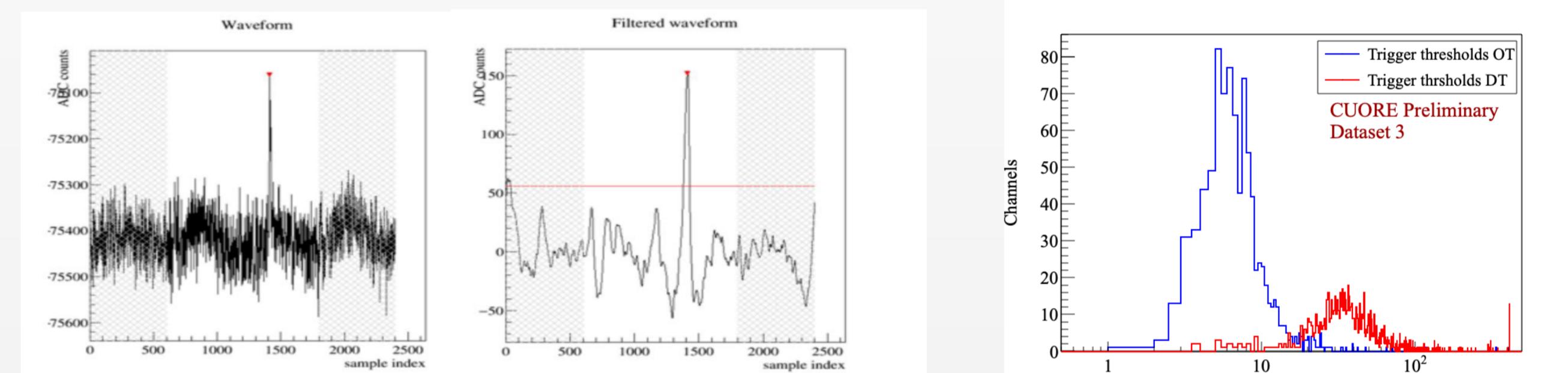
- Data taking started in Spring 2017
- After initial data taking phase, significant effort devoted to understanding the system and optimising data taking conditions
- Since March 2019 data taking is continuing smoothly with $\sim 90\%$ uptime, at operating temperature 11.8 mK \rightarrow 15 mK (from July 2021). Data taking rate ~ 50 kg/month



CUORE “data set”:
 ~1 month of physics data taking with a few days of calibration at the start and end. Continuous monitoring of detectors resistance/temperature and noise stability (set-up)

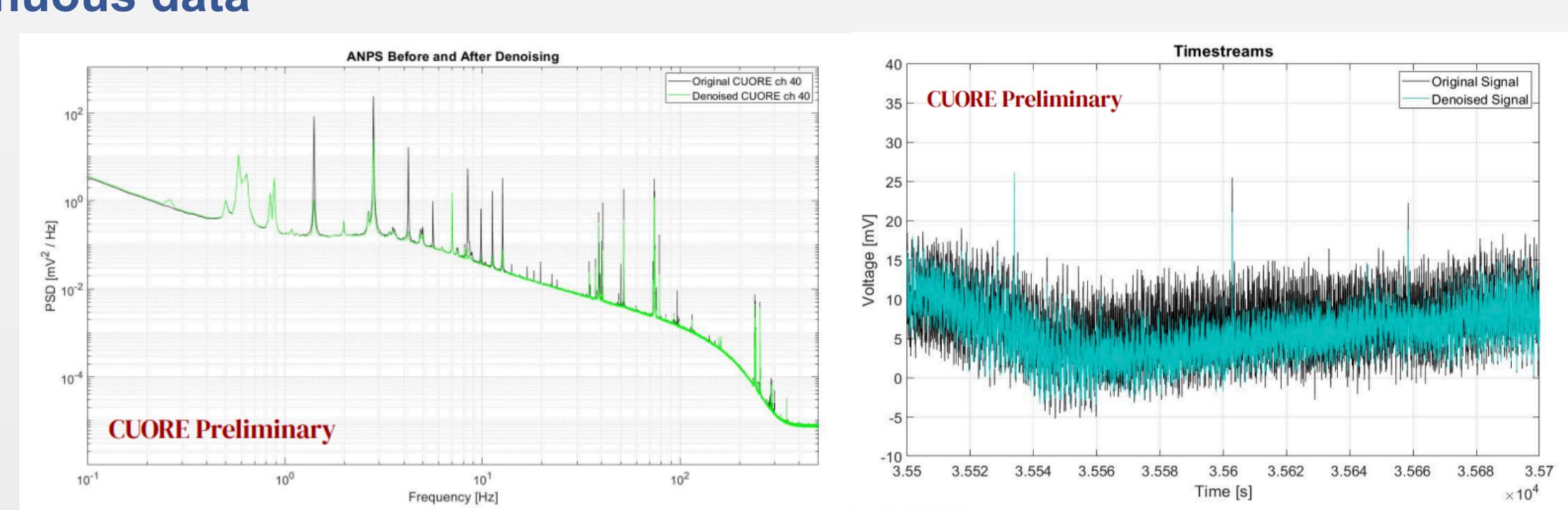
Triggering pulses

- Online Derivative Trigger (DT): threshold on the derivative of the data-stream
- Offline Optimal Trigger (OT): identification of pulses in the filtered data-stream



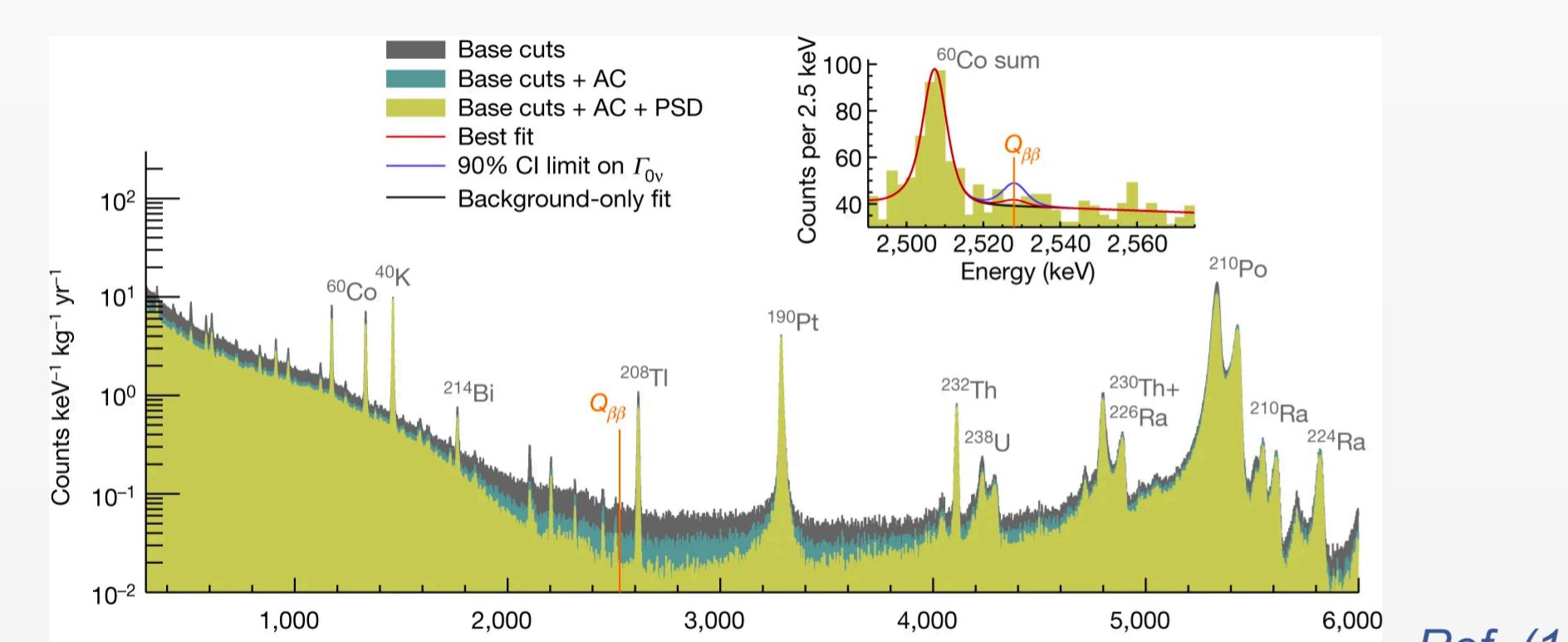
Denoising the continuous data

Remove noise from detectors using diagnostic devices (accelerometers, antennae, microphones) which identify and measure the noise sources



Search for $^{130}\text{Te} 0\nu\beta\beta$ decay

Total exposure: 1038.4 kg yr TeO_2 , 288 kg yr ^{130}Te



Half-life limit (90% C.I. including syst.)

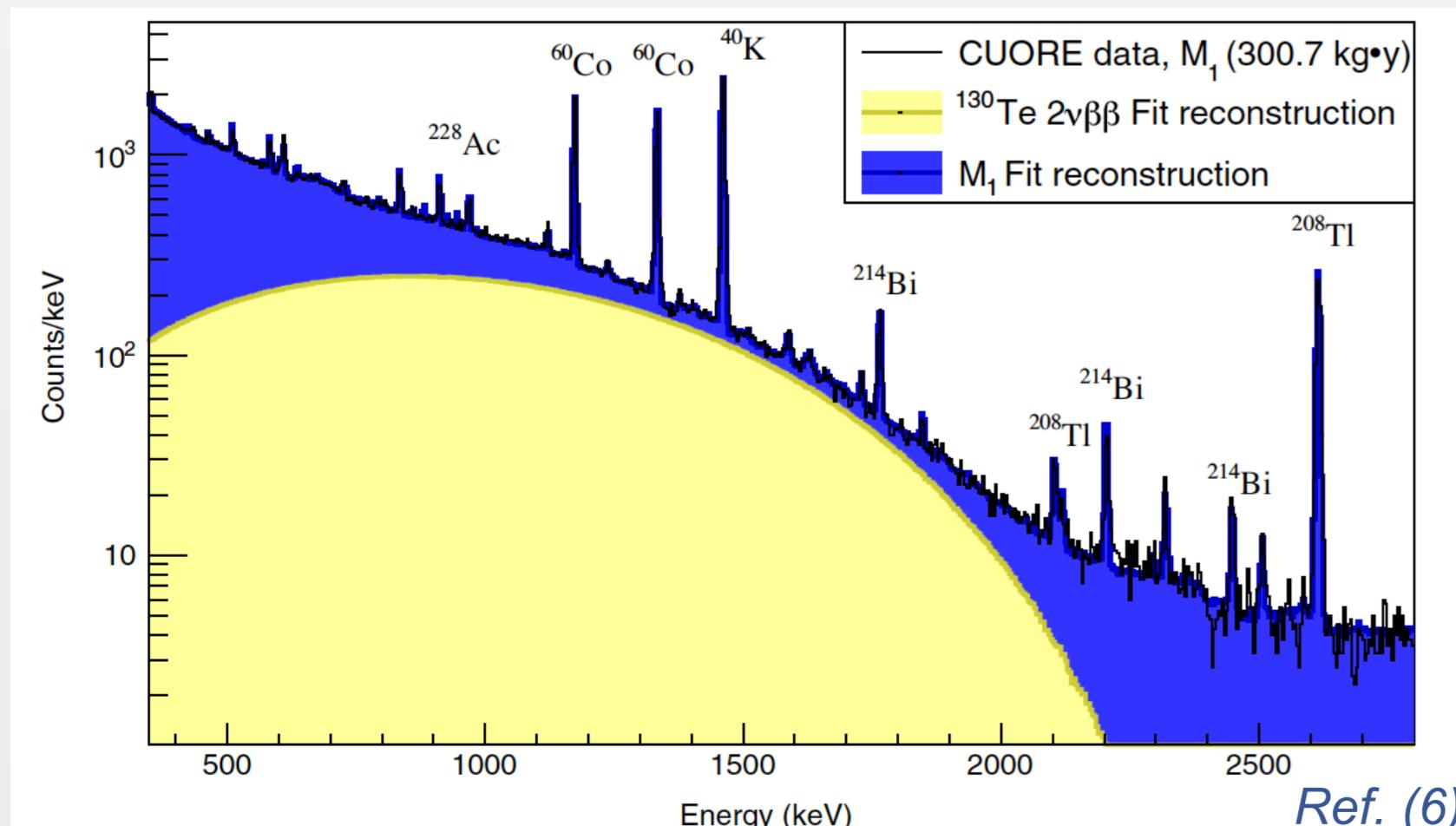
$T_{0\nu}^{1/2} (^{130}\text{Te}) > 2.2 \times 10^{25}$ yr

ROI background index: $1.49(4) \times 10^{-2}$ c/(keV · kg · yr)

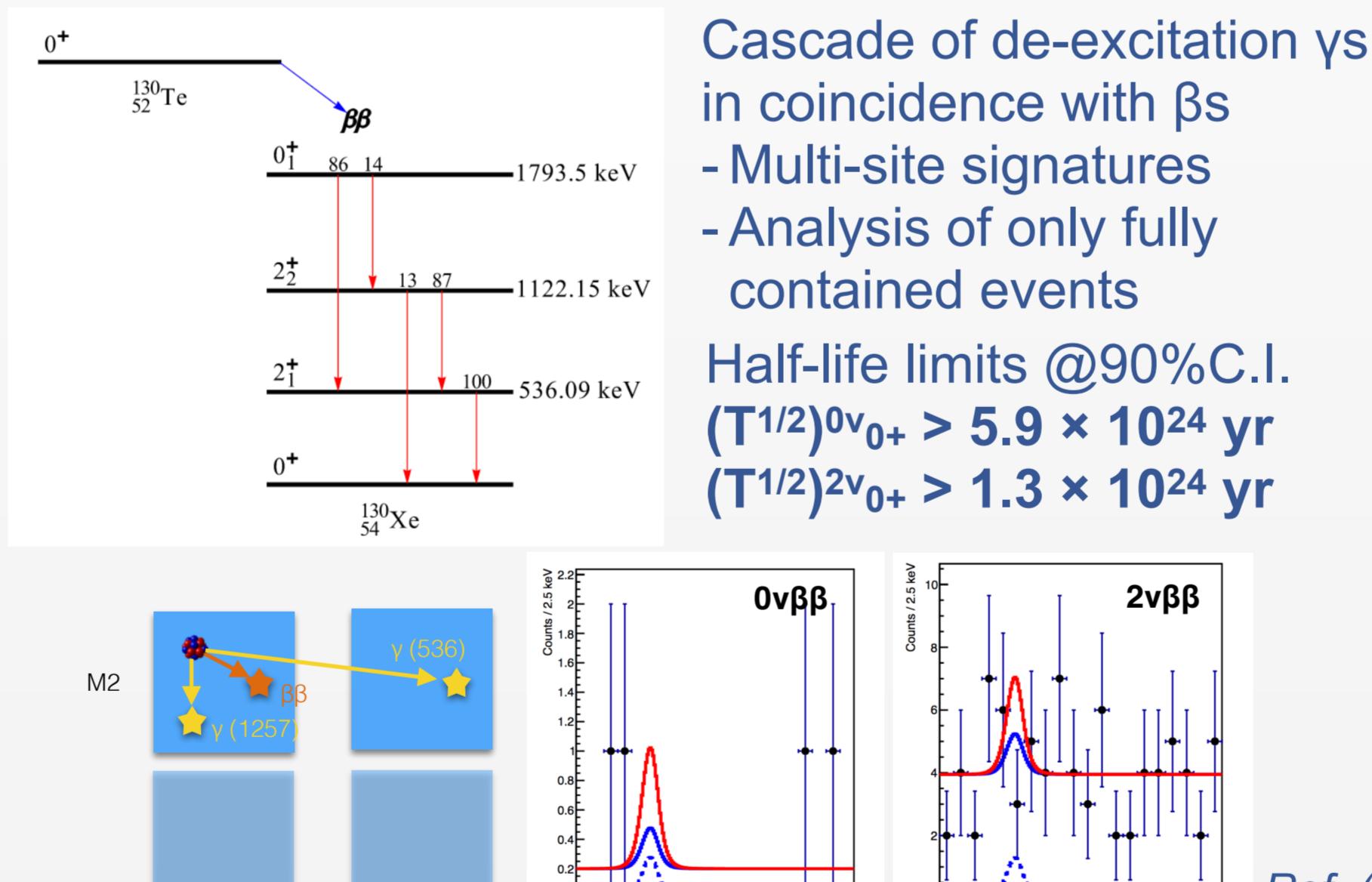
Measurement of $^{130}\text{Te} 2\nu\beta\beta$ decay

$2\nu\beta\beta$ decay: dominant component of M1 spectrum from ~ 1 to 2 MeV, due to reduced γ bags and self shielding of outer TeO_2 towers

$$T_{2\nu}^{1/2} (^{130}\text{Te}) = [7.71 \pm 0.08 \pm 0.06 (\text{stat}) \pm 0.12 \pm 0.15 (\text{syst})] \times 10^{20} \text{ yr}$$



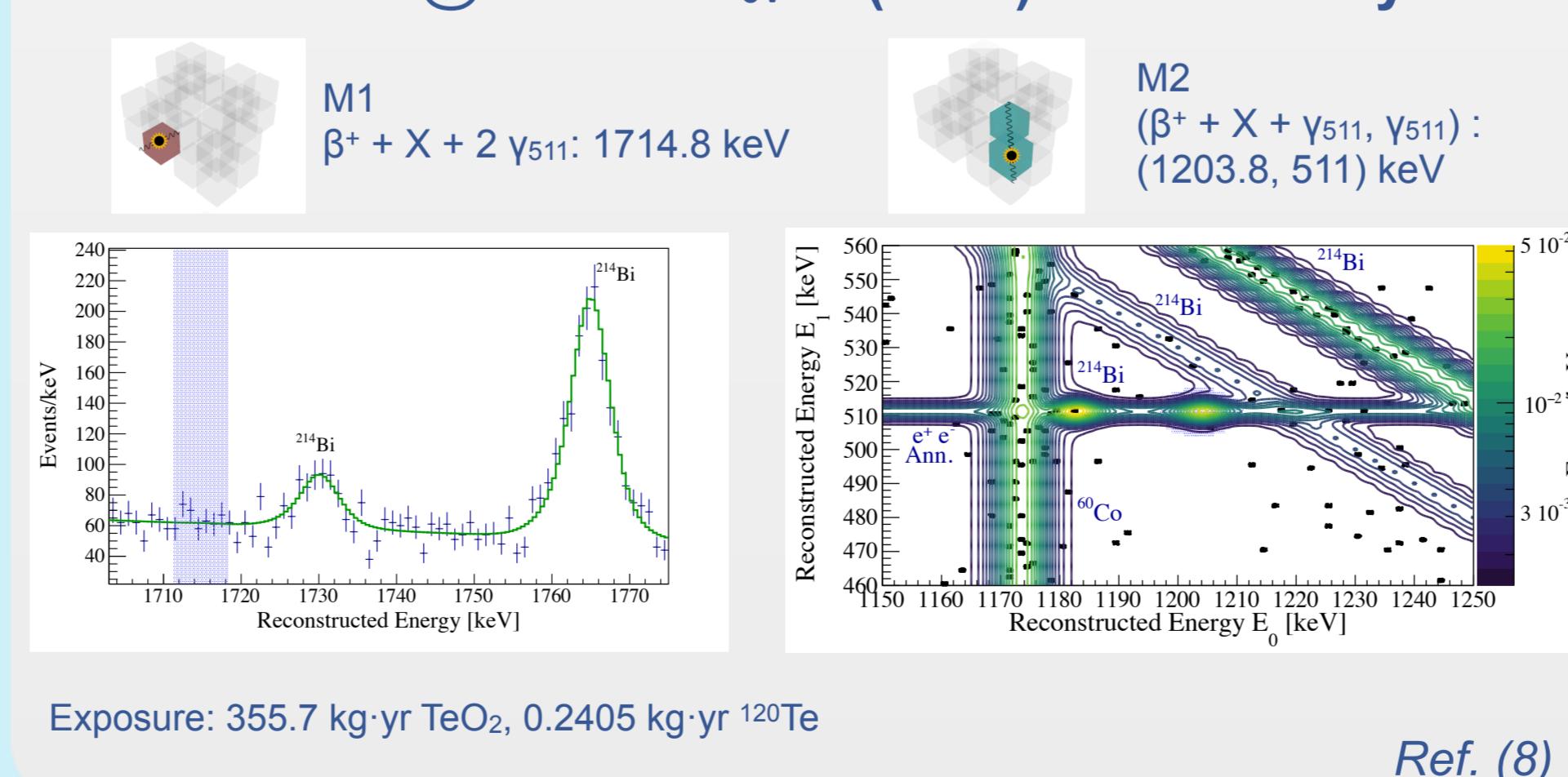
$^{130}\text{Te} \beta\beta$ decay to ^{130}Xe excited states



Search for $^{120}\text{Te} 0\nu\beta^+ + \text{EC}$ decay

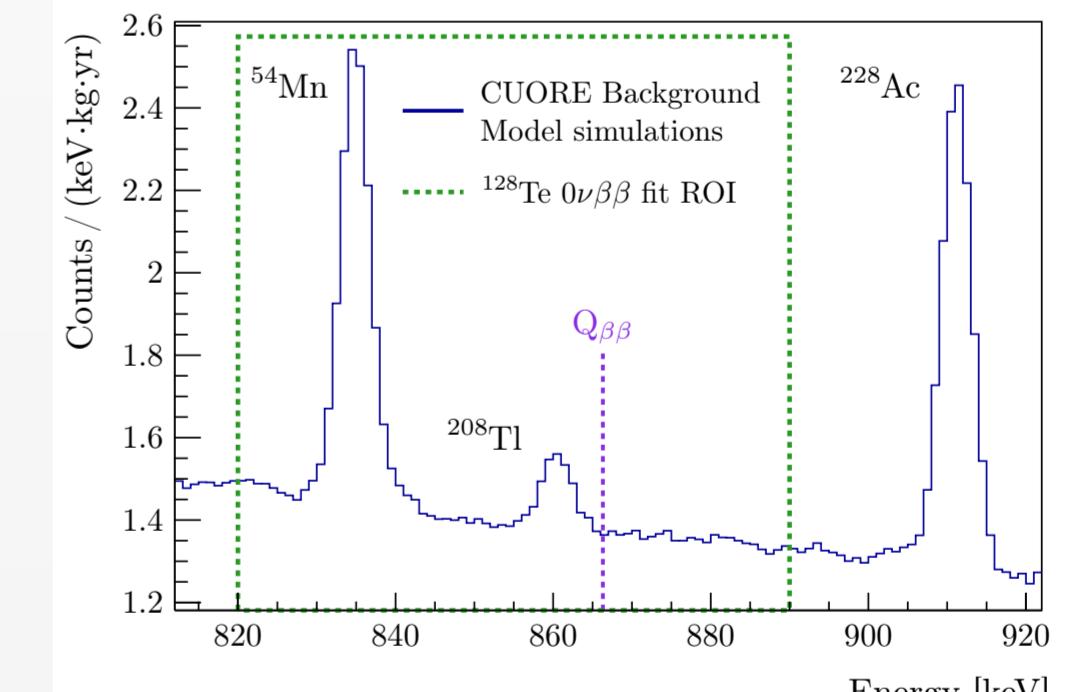
^{120}Te : $Q_{\beta\beta} = 1714.8$ keV, natural abundance: 0.09%, clear signature from e+e- annihilation and ^{120}Sn de-excitation via X-ray/Auger electrons emission

Half-life limit @90% C.I. $T_{0\nu}^{1/2} (^{120}\text{Te}) > 2.9 \times 10^{22}$ yr



Search for $^{128}\text{Te} 0\nu\beta\beta$ decay

^{128}Te : $Q_{\beta\beta} = 866.7$ keV, natural abundance: 31.74%



Exposure: 309.33 kg·yr TeO_2 , 78.56 kg·yr ^{128}Te

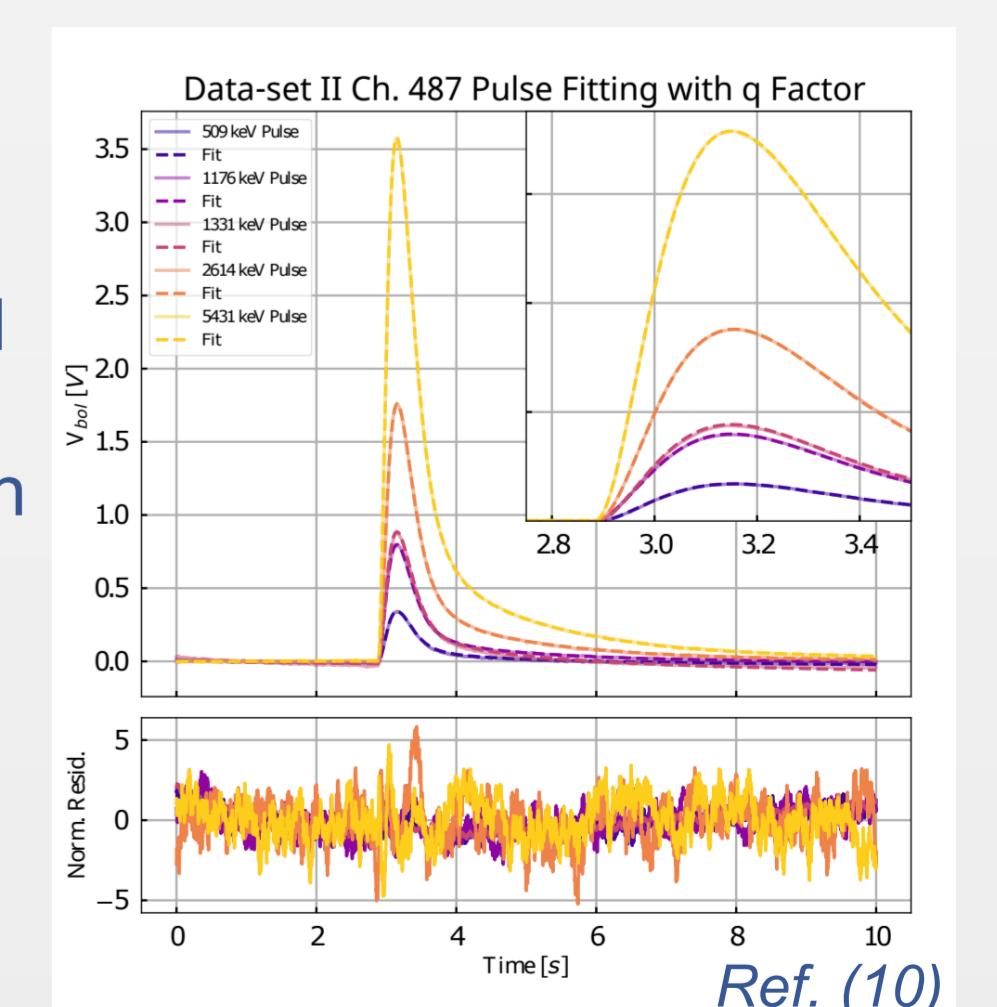
Half-life limit @90% C.I. $T_{0\nu}^{1/2} (^{128}\text{Te}) > 3.6 \times 10^{24}$ yr

Improved limit of over a factor 30 wrt to previous direct search results, and exceeded the results from geochemical experiments

Ref. (9)

Other analyses

- Model of the CUORE detectors thermal response
- Study of environmental and anthropic vibrational sources and correlation with detectors noise
- Background model and spectral shape studies
- Low energy: dark matter
- High-multiplicity events, muons and beyond SM physics



References

- (1) <https://doi.org/10.1038/s41586-022-04497-4>
- (2) <https://doi.org/10.1016/j.ppnp.2021.103902>
- (3) <https://doi.org/10.1016/j.cryogenics.2019.06.011>
- (4) <https://doi.org/10.1103/PhysRevLett.120.132501>

- (5) <https://doi.org/10.1103/PhysRevLett.124.122501>
- (6) <https://doi.org/10.1103/PhysRevLett.126.171801>
- (7) <https://doi.org/10.1140/epjc/s10052-021-09317-z>
- (8) <https://doi.org/10.48550/arXiv.2203.08684>

- (9) <https://doi.org/10.48550/arXiv.2205.03132>
- (10) <https://doi.org/10.48550/arXiv.2205.04549>
- (11) <https://doi.org/10.1142/S0217751X18430029>